AP Physics Multiple Choice Practice – Modern Physics

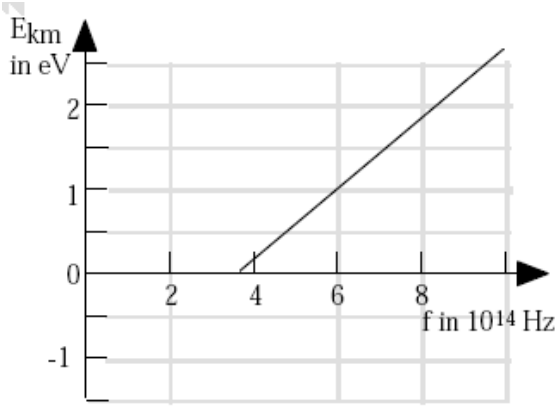
SECTION A – Quantum Physics and Atom Models

1. Light of a single frequency falls on a photoelectric material but no electrons are emitted. Electrons may be emitted if the
   A) frequency of light is decreased
   B) frequency of light is increased
   C) intensity of light is decreased
   D) intensity of light is increased
   E) velocity of light is increased

2. Which of the following types of electromagnetic radiation has the least energy per photon
   A) gamma B) infrared C) radio D) visible E) X-Rays

3. An atomic particle of mass m moving at speed v is found to have wavelength λ. What is the wavelength of a second particle with a speed 3v and the same mass
   A) (1/9) λ B) (1/3) λ C) λ D) 3 λ E) 9 λ

4. A student performs the photoelectric effect experiment and obtains the data depicted in the accompanying graph of E_{km} (max kinetic energy) of photoelectrons vs the frequency of the photons. What is the approximate work function of this material?



   A) 1.5 eV B) 2.0 eV C) 2.7 eV D) 4.0 eV E) 6.0 eV

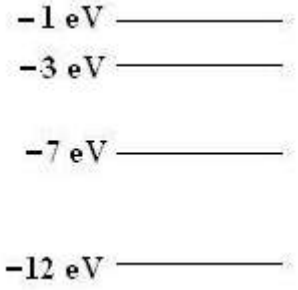
5. According to the Bohr theory of the hydrogen atom, electrons starting in the 4th energy level and eventually ending up in the ground state, could produce a total of how many lines in the hydrogen spectra?
   A) 7 B) 6 C) 5 D) 4 E) 3

6. In Rutherfords famous gold foil scattering experiment, he found that most alpha particles would pass through the foil undeflected. Which of the following nuclear properties can be inferred from this observation.
   A) The nucleus must have a positive charge
   B) Most of the mass of an atom is in the nucleus
   C) The nucleus contains both protons and neutrons
   D) The diameter of the nucleus is small compared to the diameter of the atom
   E) none of the above.

7. Which of the following is best explained only by the wave theory of light
   A) blackbody radiation
   B) the Compton effect
   C) the photoelectric effect
   D) pair–production
   E) diffraction

8. In the photoelectric effect experiment, a stopping potential of V_{stop} is needed when light of frequency f_o shines on the electron-emitting metal surface. If the metal surface on which the light shines is replaced with a new material that has half the work function, what is the new stopping potential, V_{new}, for light of frequency shining on it?
   a) $V_{new} > 2V_{stop}$ b) $V_{new} = 2\ V_{stop}$ c) $V_{stop} < V_{new} < 2V_{stop}$
   d) $V_{new} = V_{stop}$ e) It is indeterminate with the given information

9. The diagram to the right shows the lowest four energy levels for an electron in a hypothetical atom. The electron is excited to the −1 *eV* level of the atom and transitions to the lowest energy state by emitting only two photons. Which of the following energies could not belong to either of the photons?
   (A) 2 *eV* (B) 4 *eV* (C) 5 *eV* (D) 6 *eV* (E) 9 *eV*

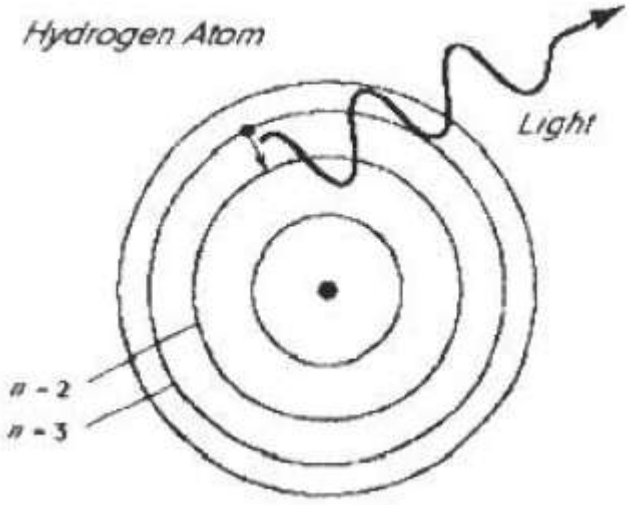


10. Monochromatic light falling on the surface of an active metal causes electrons to be ejected from the metallic surface with a maximum kinetic energy of E. What would happen to the maximum energy of the ejected electrons if the frequency of the light were doubled?
   A) the maximum energy of the electrons would be less than ½ E
   B) the maximum energy of the electrons would be ½ E
   C) the maximum energy of the electrons would be (√2) E
   D) the maximum energy of the electrons would be 2E
   E) the maximum energy of the electrons would be greater than 2E

11. If the electrons in an electron microscope are traveling with a velocity of $1.6\text{x}10^{7}$ m/s, what would be the effective wavelength of the electrons?
   A) $1.2\text{x}10^{-8}$ m B) $6.6\text{x}10^{-9}$ m C) $4.5\text{x}10^{-11}$ m D) $2.6\text{x}10^{-11}$ m E) $8.6\text{x}10^{-17}$ m

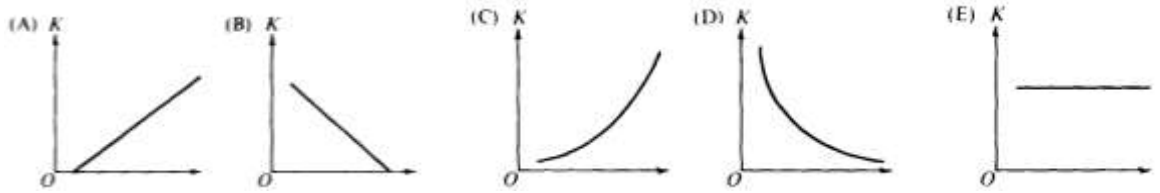
12. A very slow proton has its kinetic energy doubled. What happens to the protons corresponding deBroglie wavelength
   A) the wavelength is decreased by a factor of √2
   B) the wavelength is halved
   C) there is no change in the wavelength
   D) the wavelength is increased by a factor of √2
   E) the wavelength is doubled.

13. The diagram shows light being emitted due to a transition from the n=3 to the n=2 level of a hydrogen atom in the Bohr model. If the transition were from the n=3 to the n=1 level instead, the light emitted would have
   A) lower frequency B) less energy
   C) longer wavelength D) greater speed
   E) greater momentum



14. Which color of light emitted from an atom would be associated with the greatest change in energy of the atom?
(A) Blue (B) Green (C) Red (D) Violet (E) Yellow

Questions 15-16 relate to the photoelectric effect and the five graphs below



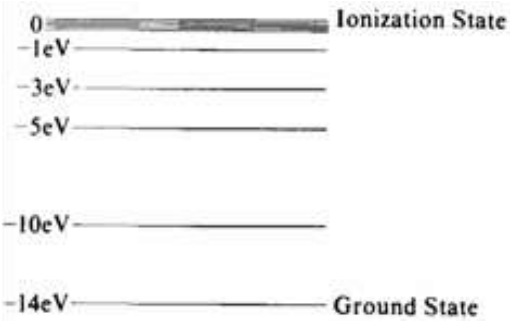
15. Which graph best shows the maximum kinetic energy K of the photoelectrons as a function of the frequency of incident light?
(A) A (B) B (C) C (D) D (E) E

16. Which graph best shows the maximum kinetic energy K of a photoelectron as a function of the intensity of incident light?
(A) A (B) B (C) C (D) D (E) E

17. Electrons that have been accelerated from rest through a potential difference of 150 volts have a de Broglie wavelength of approximately 1 Angstrom (10^{-10} meter). In order to obtain electrons whose de Broglie wavelength is 0.5 Angstrom (5×10^{-11} meter), what accelerating potential is required?
(A) 37.5 V (B)75 V (C)300 V (D)600 V (E)22,500 V

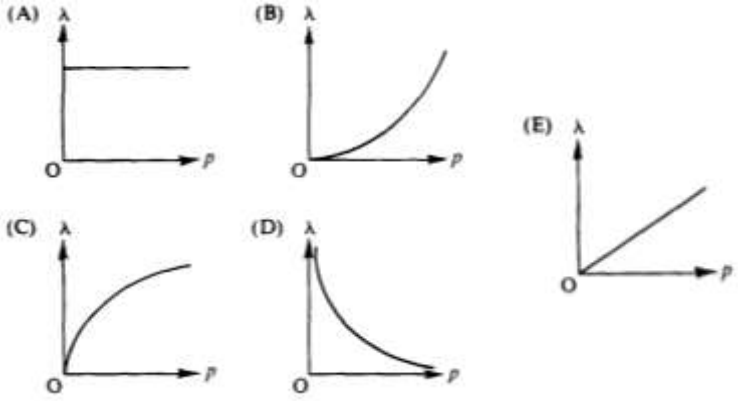
18. According to the Bohr model of the atom, electrons orbit the nucleus in definite orbits. According to the laws of classical physics, this model would be impossible because
(A) the positively charged nucleus attracts the electrons
(B) Coulomb's law applies
(C) accelerating electrons radiate energy
(D) there is a centripetal force on the electrons
(E) angular momentum is conserved

19. The energy level diagram is for a hypothetical atom. A gas of these atoms initially in the ground state is irradiated with photons having a continuous range of energies between 7 and 10 electron volts. One would expect photons of which of the following energies to be emitted from the gas?
(A) 1, 2, and 3 eV only
(B) 4, 5, and 9 eV only
(C) 1, 3, 5, and 10 eV only
(D) 1, 5, 7, and 10 eV only
(E) Since the original photons have a range of energies, one would expect a range of emitted photons with no particular energies.



20. All of the following are properties of x-rays EXCEPT:
(A) They penetrate light materials.
(B) They ionize gases.
(C) They are deflected by magnetic fields.
(D) They discharge electrified bodies.
(E) They are diffracted by crystals.

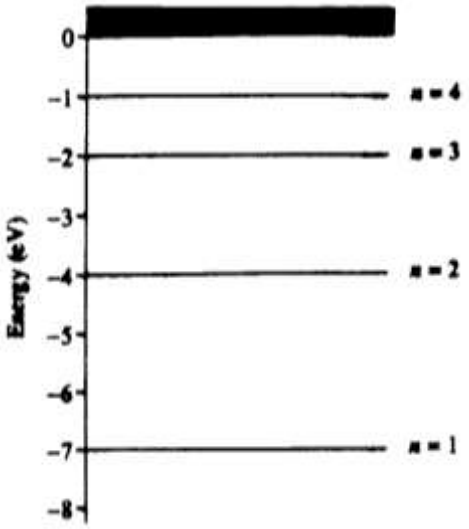
21. Which of the following graphs best represents the de Broglie wavelength λ of a particle as a function of the linear momentum p of the particle?



22. The scattering of alpha particles by a thin gold foil was measured by Geiger and Marsden. The Rutherford model of the atom was proposed in order to explain why
    (A) more particles scattered through angles greater than 90° than through angles less than 90°
    (B) the fraction of particles scattered through large angles was too large to be explained by previous models of the atom
    (C) no particles passed through the foil undeflected
    (D) the most common scattering angle was about 90°
    (E) the most common scattering angle was about 180°

Questions 23-24

A hypothetical atom has four energy states as shown.



23. Which of the following photon energies could NOT be found in the emission spectra of this atom after it has been excited to the n = 4 state?
    (A) 1 eV (B) 2 eV (C) 3 eV (D) 4 eV (E) 5 eV

24. Which of the following transitions will produce the photon with the longest wavelength?
    (A) n = 2 to n = 1
    (B) n = 3 to n = 1
    (C) n = 3 to n = 2
    (D) n = 4 to n = 1
    (E) n = 4 to n = 3

25. Of the following phenomena, which provides the best evidence that light can have particle properties?
    (A) Interference of light in thin films (B) Electromagnetic radiation (C) Photoelectric effect
    (D) Electron diffraction (E) X-ray diffraction

26. Of the following phenomena, which provides the best evidence that particles can have wave properties?
    (A) The absorption of photons by electrons in an atom
    (B) The alpha-decay of radioactive nuclei
    (C) The interference pattern produced by neutrons incident on a crystal
    (D) The production of x-rays by electrons striking a metal target
    (E) The scattering of photons by electrons at rest

27. In the photoelectric effect, the maximum speed of the electrons emitted by a metal surface when it is illuminated by light depends on which of the following?
I. Intensity of the light
II. Frequency of the light
III. Nature of the photoelectric surface
(A) I only (B) III only (C) I and II only (D) II and III only (E) I, II, and III

28. In the Bohr model of the atom, the postulate stating that the orbital angular momentum of the electron is quantized can be interpreted in which of the following ways?
(A) An integral number of electron wavelengths must fit into the electron's circular orbit.
(B) Only one electron can exist in each possible electron state.
(C) An electron has a spin of 1/2.
(D) The atom is composed of a small, positively charged nucleus orbited by electrons.
(E) An incident photon is completely absorbed when it causes an electron to move to a higher energy state.

29. Quantum transitions that result in the characteristic sharp lines of the X-ray spectrum always involve
(A) the inner electron shells (B) electron energy levels that have the same principal quantum number
(C) emission of beta particles from the nucleus (D) neutrons within the nucleus
(E) protons within the nucleus

30. Which of the following experiments provided evidence that electrons exhibit wave properties?
I. Millikan oil-drop experiment
II. Davisson-Germer electron-diffraction experiment
III. J. J. Thomson's measurement of the charge-to-mass ratio of electrons

(A) I only (B) II only (C) I and III only (D) II and III only (E) I, II, and III

31. If the momentum of an electron doubles, its de Broglie wavelength is multiplied by a factor of
(A) 1/4 (B)1/2 (C) 1 (D) 2 (E) 4

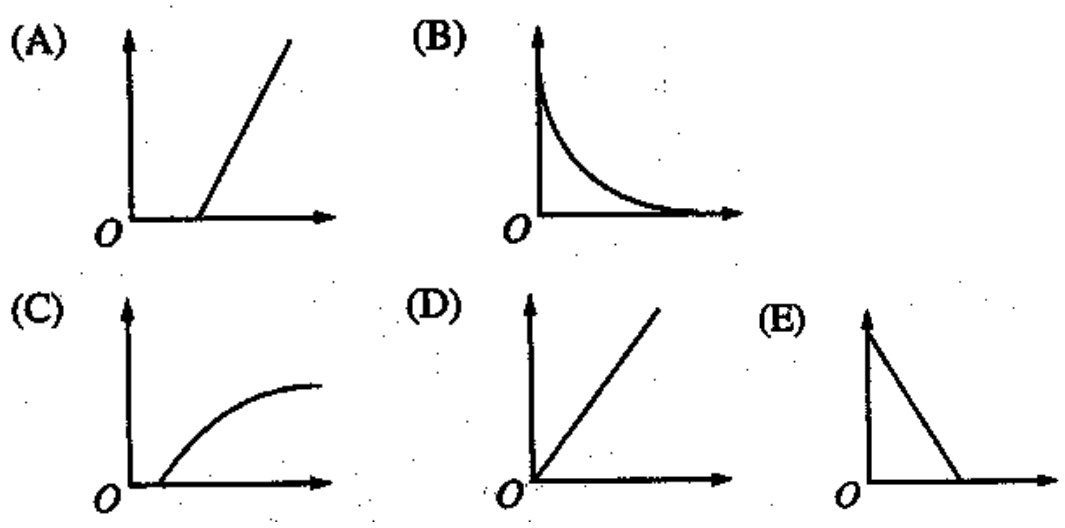
32. Quantum concepts are critical in explaining all of the following EXCEPT
(A) Rutherford's scattering experiments (B) Bohr's theory of the hydrogen atom
(C) Compton scattering (D) the blackbody spectrum (E) the photoelectric effect

33. If photons of light of frequency *f* have momentum *p*, photons of light of frequency *2f* will have a momentum of
(A) *2p* (B) $\sqrt{2}p$ (C) *p* (D) $\frac{p}{\sqrt{2}}$ (E) ½ *p*

34. In an experiment, light of a particular wavelength is incident on a metal surface, and electrons are emitted from the surface as a result. To produce more electrons per unit time but with less kinetic energy per electron, the experimenter should do which of the following?
(A) Increase the intensity and decrease the wavelength of the light.
(B) Increase the intensity and the wavelength of the light.
(C) Decrease the intensity and the wavelength of the light.
(D) Decrease the intensity and increase the wavelength of the light.
(E) None of the above would produce the desired result.

35. Which of the following imposes a limit on the number of electrons in an energy state of an atom?
(A) The Heisenberg uncertainty principle
(B) The Pauli exclusion principle
(C) The Bohr model of the hydrogen atom
(D) The theory of relativity
(E) The law of conservation of energy

Questions 36-37 relate to the photoelectric effect. For each question, choose an answer from the following graphs



36. Which graph shows the maximum kinetic energy of the emitted electrons versus the frequency of the light?
(A) A (B) B (C) C (D) D (E) E

37. Which graph shows the total photoelectric current versus the intensity of the light for a fixed frequency above the cutoff frequency?
(A) A (B) B (C) C (D) D (E) E

38. A 50,000 W radio station transmits waves of wavelength 4 m. Which of the following is the best estimate of the number of photons it emits per second?
(A) 10^{8} (B) 10^{22} (C) 10^{30} (D) 10^{40} (E) 10^{56}

39. The work function for a metal is ϕ. What is the threshold frequency of incident light required for the emission of photoelectrons from a cathode made of that metal?
A) ϕ / h B) h / ϕ C) ϕh D) ϕ / hc E) hc / ϕ

40. Two monochromatic light beams, one red and one green, have the same intensity and the same cross sectional area. How does the energy of each photon and the number of photons crossing a unit area per second in the red beam compare with those of the green beam?

	Energy of Photon	Number of Photons Crossing Unit Area per Second
(A)	Same	Same
(B)	Greater for red	Less for red
(C)	Greater for red	Greater for red
(D)	Less for red	Less for red
(E)	Less for red	Greater for red

41. In an x-ray tube, electrons striking a target are brought to rest, causing x-rays to be emitted. In a particular x-ray tube, the maximum frequency of the emitted continuum x-ray spectrum is f_o. If the voltage across the tube is doubled, the maximum frequency is
A) $f_o / 2$ B) $f_o / \sqrt{2}$ C) f_o D) $\sqrt{2}\, f_o$ E) $2f_o$

SECTION B – Nuclear Physics

1. An atomic mass unit is approximately equal to the mass of a(n)
   A) alpha particle B) electron C) photon D) positron E) proton

2. A radioactive oxygen $^{15}O_8$ nucleus emits a positron and becomes
   A) $^{14}N_7$ B) $^{15}N_7$ C) $^{15}O_8$ D) $^{14}F_9$ E) $^{15}F_9$

3. A radon $^{220}Rn_{86}$ nucleus emits an alpha particle becomes a
   A) $^{216}Po_{84}$ B) $^{220}At_{85}$ C) $^{220}Rn_{86}$ D) $^{220}Fr_{87}$ E) $^{224}Ra_{88}$

4. A potassium $^{40}K_{19}$ nucleus emits a B^- and becomes:
   A) $^{36}Cl_{17}$ B) $^{44}Sc_{21}$ C) $^{40}Ar_{18}$ D) $^{40}K_{19}$ E) $^{40}Ca_{20}$

5. A photon with frequency f behaves as if it had a mass equal to
   A) hfc^2 B) hf / c^2 C) c^2 / hf D) fc^2 / h E) h / fc^2

6. What does the ? represent in the nuclear reaction $^2H_1 + ^2H_1 \rightarrow ^3He_2 + ?$
   A) an alpha B) a beta C) a gamma D) a neutron E) a proton

7. What does the ? represent in the nuclear reaction $^6Li_3 + ? \rightarrow ^7Li_3$
   A) an alpha particle B) a deuteron C) an electron D) a neutron E) a proton

8. An alpha particle is the same as
   A) a helium nucleus B) a positron C) an electron D) a high energy photon E) a deuteron

9. The following equation is an example of what kind of nuclear reaction

   $$^{235}U_{92} + ^1n_0 \rightarrow ^{133}Sb_{51} + ^{99}Nb_{41} + 4\ (^1n_0)$$

   A) fission B) fusion C) alpha decay D) beta decay E) positron decay

10. The following equation is an example of what kind of nuclear reaction

    $$^{12}C_6 + ^4He_2 \rightarrow ^{16}O_8 + \text{energy}$$

    A) fission B) fusion C) alpha decay D) beta decay E) positron decay

11. During a particular kind of radioactive decay, a particle is emitted from the nucleus of an atom and the atom's atomic number increases by one. This decay necessarily involves the emission of _____ from the nucleus
    A) an alpha particle B) a beta particle C) a gamma ray D) a proton E) a neutron

12. A nucleus of $^{235}U_{92}$ disintegrates to $^{207}Pb_{82}$ in about a billion years by emitting 7 alpha particles and x beta particles, where x is
    A) 3 B) 4 C) 5 D) 6 E) 7

13. The following nuclear reaction occurs:

    $$^4_2He + ^9_4Be \rightarrow ^{12}_6C + ^A_ZX.$$ What is ^A_ZX ?

    (A) a proton (B) an electron (C) a positron (D) an alpha particle (E) a neutron

14. A scientist claims to have perfected a technique in which he can spontaneously convert an electron completely into energy in the laboratory without any other material required. What is the conclusion about this claim from our current understanding of physics?
    (a) This is possible because Einstein's equation says that mass and energy are equivalent… it is just very difficult to achieve with electrons
    (b) This is possible and it is done all the time in the high-energy physics labs.
    (c) The scientist is almost correct… except that in converting the electron to energy, an electron's anti-particle is produced in the process as well.
    (d) The scientist is almost correct… except that in converting the electron to energy, a proton is produced in the process as well.
    (e) This is not possible because charge conservation would be violated.

15. A new element, named Physonium (symbol Phys) is discovered to undergo double alpha decay and beta decay simultaneously. Amazingly, this causes the material to decay into an element called Awsomeonium (symbol Oo). What is the correct representation of the (Oo)?

$$^{2006}_{200}Phys \rightarrow {}^{4}_{2}\alpha + {}^{4}_{2}\alpha + {}^{0}_{-1}e + {}^{?}_{?}Oo$$

(a) $^{1998}_{195}Oo$ (b) $^{2006}_{195}Oo$ (c) $^{1998}_{203}Oo$ (d) $^{2014}_{203}Oo$ (e) $^{1998}_{197}Oo$

16. The most common isotope of Uranium, $^{238}U_{92}$, radioactively decays into lead, $^{206}Pb_{82}$, by a means of a series of alpha and beta particle emissions. How many of each particle must be emitted.
    A) 32 alphas, 10 betas B) 16 alphas, 16 betas C) 16 alphas, 8 betas
    D) 8 alphas, 6 betas E) 4 alphas, 18 betas

17. Rutherford was the first person to artificially transmute one element into another (nitrogen to oxygen). A nuclear equation for his reaction could be written as follows:

$$\frac{4}{2}He + \frac{14}{7}N \rightarrow \frac{17}{8}O + ?$$

    The unknown particle in the above equation is
    A) a proton B) a neutron C) an electron D) a gamma ray E) an alpha particle

18. When a radioactive nucleus emits a gamma ray the number of
    A) protons increases by one while the number of neutrons decreases by one.
    B) protons decrease by one while the number of neutrons increases by one.
    C) protons and neutrons each decrease by two
    D) protons and neutrons each increase by two
    E) protons and neutrons remain unchanged

19. A nucleus of polonium–218 ($\frac{218}{84}Po$) emits an alpha particle ($\frac{4}{2}\alpha$). The next two elements in radioactive decay chain each emit a beta particle ($\frac{0}{-1}B^{-}$). What would be the resulting nucleus after these three decays have occurred?
    A) $\frac{214}{82}Pb$ B) $\frac{214}{84}Po$ C) $\frac{214}{85}At$ D) $\frac{222}{85}At$ E) $\frac{222}{86}Rn$

20. $^{235}_{92}U + ^{1}_{0}n \rightarrow 3\,^{1}_{0}n + ^{142}_{56}Ba + \_\_\_\_\_$

The additional product of the nuclear fission reaction shown above is

(A) $^{91}_{36}Kr$ (B) $^{92}_{35}Br$ (C) $^{93}_{36}Kr$ (D) $^{93}_{37}Rb$ (E) $^{94}_{37}Rb$

21. The nuclide $^{214}\text{Pb}_{82}$ emits an electron and becomes nuclide X. Which of the following gives the mass number and atomic number of nuclide X?

	Mass Number	Atomic Number
(A)	210	80
(B)	210	81
(C)	213	83
(D)	214	81
(E)	214	83

22. The nuclear reaction $X \rightarrow Y + Z$ occurs spontaneously. If M_x, M_Y, and M_Z are the masses of the three particles. which of the following relationships is true'?

(A) $M_x < M_y - M_z$ (B) $M_x < M_y + M_z$ (C) $M_x > M_y + M_z$ (D) $M_x - M_y < M_z$ (E) $M_x - M_z < M_y$

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{1}H + ^{1}_{1}H + 4MeV$$

23. The equation above is an illustration of

(A) artificially produced radioactive decay (B) naturally occurring radioactive decay
(C) nuclear disintegration (D) nuclear fission
(E) nuclear fusion

24. A proton collides with a nucleus of $^{14}_{7}N$. If this collision produces a nucleus of $^{11}_{6}C$ and one other particle, that particle is (A) a proton (B) a neutron (C) a deuteron (D) an α particle (E) a β particle

25. A nucleus of tritium contains 2 neutrons and 1 proton. If the nucleus undergoes beta decay, emitting an electron, the nucleus is transmuted into

(A) the nucleus of an isotope of helium (B) the nucleus of an isotope of lithium (C) an alpha particle
(D) a triton (E) a deuteron

26. Which of the following statements is true of a beta Particle?

(A) Its speed in a vacuum is 3×10^8 m/s.
(B) It has a charge equal and opposite to that of an alpha particle.
(C) It is more penetrating than a gamma ray of the same energy.
(D) It has a mass of about 1,840 times that of a proton.
(E) It can exhibit wave properties.

Questions 27-28

An electron and a positron, each of mass 9.1×10^{-31} kilogram, are in the same general vicinity and have very small initial speeds. They then annihilate each other, producing two photons.

27. What is the approximate energy of each emerging photon?

(A) 0.51 MeV (B) 2.0 MeV (C) 4.0 MeV (D) 6.6 MeV
(E) It cannot be determined unless the frequency of the photon is known.

28. What is the angle between the paths of the emerging photons?

(A) 0° (B) 30º (C) 45° (D) 90° (E) 180°

Questions 29-30 deal with nuclear fission for which the following reaction is a good example.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{138}_{56}Ba + ^{95}_{36}Kr + neutrons + release\ energy$$

29. The total number of free neutrons in the products of this reaction is
(A) 2 (B) 3 (C) 4 (D) 5 (E) 6

30. Which of the following statements is always true for neutron-induced fission reactions involving $^{235}_{92}U$?
I. The end products always include Ba and Kr.
II. The rest mass of the end products is less than that of $^{235}_{92}U + ^{1}_{0}n$.
III. The total number of nucleons (protons plus neutrons) in the end products is less than that in $^{235}_{92}U + ^{1}_{0}n$.
(A) II only (B) III only (C) I and II only (D) I and III only (E) I, II, and III

31. Forces between two objects which are inversely proportional to the square of the distance between the objects include which of the following?
I. Gravitational force between two celestial bodies
II. Electrostatic force between two electrons
III. Nuclear force between two neutrons
(A) I only (B) III only (C) I and II only (D) II and III only (E) I, II, and III

32. Atoms of isotopes of the same element contain the same number of
(A) protons but a different number of neutrons (B) electrons but a different number of protons
(C) neutrons but a different number of protons (D) neutrons as electrons (E) protons as neutrons

33. Quantities that are conserved in all nuclear reactions include which of the following?
I. Electric charge
II. Number of nuclei
III. Number of protons

(A) I only (B) II only (C) I and III only (D) II and III only (E) I, II, and III

34. A negative beta particle and a gamma ray are emitted during the radioactive decay of a nucleus of $^{214}_{82}Pb$. Which of the following is the resulting nucleus?
(A) $^{210}_{80}Hg$ (B) $^{214}_{81}Tl$ (C) $^{213}_{83}Bi$ (D) $^{214}_{83}Bi$ (E) $^{218}_{84}Po$

35. Which of the following statements about the number of protons Z and the number of neutrons N in stable nuclei is true?
(A) All stable nuclei have Z = N.
(B) Only heavy stable nuclei have Z = N.
(C) Heavy stable nuclei tend to have Z < N.
(D) All light stable nuclei have Z< N.
(E) All light stable nuclei have Z > N.

36. When ^{10}B is bombarded by neutrons, a neutron can be absorbed and an alpha particle (^{4}He) emitted. If the ^{10}B target is stationary, the kinetic energy of the reaction products is equal to the.

(A) kinetic energy of the incident neutron
(B) total energy of the incident neutron
(C) energy equivalent of the mass decrease in the reaction
(D) energy equivalent of the mass decrease in the reaction, minus the kinetic energy of the incident neutron
(E) energy equivalent of the mass decrease in the reaction, plus the kinetic energy of the incident neutron

37. $^{226}_{88}\mathrm{Ra}$ decays into $^{222}_{86}\mathrm{Rn}$ plus

(A) a proton (B) a neutron (C) an electron

(D) a helium nucleus $\left(^{4}_{2}\mathrm{He}\right)$ (E) a deuteron $\left(^{2}_{1}\mathrm{H}\right)$

38. Correct statements about the binding energy of a nucleus include which of the following?

I. It is the energy needed to separate the nucleus into its individual protons and neutrons.
II. It is the energy liberated when the nucleus is formed from the original nucleons.
III. It is the energy equivalent of the apparent loss of mass of its nucleon constituents.

(A) I only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III